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GRAPHICAL INTEGRATION IN HYDRAULIC PROBLEMS

BY SAMUEL SHULITS*

SYNOPSIS

GRAPHICAL integration is well known to the hydraulic engineer in the form of the mass diagram for storage problems; yet there are also many other problems which can be solved much more simply and quickly by the method of graphical integration without any sacrifice in accuracy.

In graphical integration use is made of the so-called summation curve, the curve of the integral of the function being investigated. The construction and properties of the summation curve are presented here and its use illustrated by two examples.

CONSTRUCTION AND PROPERTIES OF THE SUMMATION CURVE

The summation curve in general is the curve of the integral of the function, $f(x) = y$, being considered. The ordinate (s) to the summation line at any abscissa (x) represents the sum of the ordinates of the curve of the function up to the point x , or, in other words, it represents the area ($\int_0^x y dx$) under the curve up to the point x . The ordinate, s_e (called

* Hydraulic engineer. As Freeman Traveling Fellow of the Boston Society of Civil Engineers, the author has spent more than a year with Prof. A. Schoklitsch, Dean of the Civil Engineering Department of the German Technical University in Brunn, Czechoslovakia. This article presents methods treated by Schoklitsch in his "Graphische Hydraulik" and his new "Der Wasserbau." The latter book is now being translated into the English language by the writer under the auspices of Dr. John R. Freeman and Dr. Samuel W. Stratton of the Massachusetts Institute of Technology.

the end-ordinate hereafter) at the end of the summation curve is then the total area under the curve of the function; and this end-ordinate divided by the base of the area under the curve is the mean value of the function.

Since the summation curve represents a sum, it follows that the summation curve is an inclined straight line when the function y is a constant, and that the summation curve is a horizontal line when $y=0$.

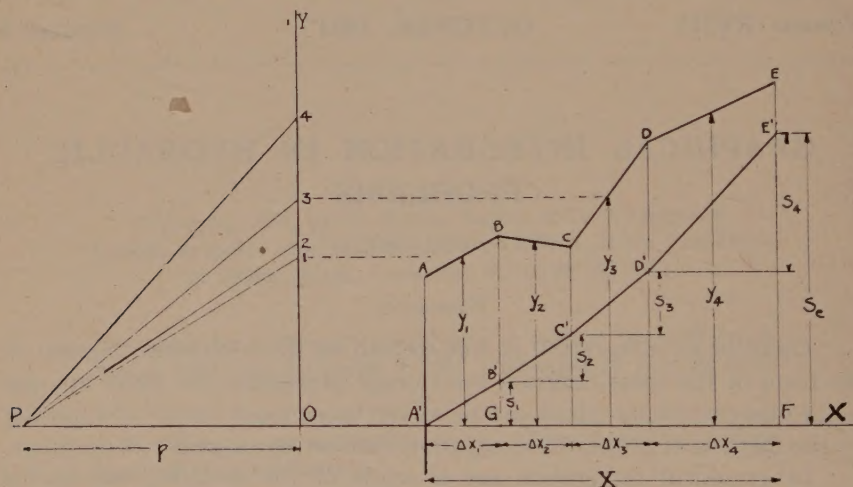


FIG. 1. — CONSTRUCTION OF SUMMATION CURVE

Let the curve $ABCDE$ (Fig. 1) represent the variation of $y=f(x)$. The curve can then be considered as made up of a series of straight lines AB , BC , CD , DE , drawn to fit the curve $ABCDE$ as closely as possible. The area under $ABCDE$ is then made up of a number of trapezoids whose tops are the lines AB , BC , CD , DE , and whose bases are Δx_1 , Δx_2 , Δx_3 , Δx_4 ; let the mean ordinates of these trapezoids be y_1 , y_2 , y_3 , y_4 , and their areas, a_1 , a_2 , a_3 , a_4 . Project these mean ordinates on the vertical line (OY) at the left; take a pole (P) at some polar distance (p) from this vertical line and draw strings from P to the projected points. The slopes of these strings are then the slopes of the elements of the summation curve; the string $P1$ is the slope of the summation curve of the area under AB ; $P2$, the slope of the summation curve of the area under BC ; and so on. The summation curve $A'B'C'D'E'$ is accordingly constructed by drawing $A'B'$ parallel to $P1$, $B'C'$ parallel to $P2$, and so

forth. The process is nothing more than the graphical summation of the areas of contiguous trapezoids and rectangles.

This geometric construction is proven by considering the similar triangles $P10$ and $A'B'G$ where

$$\frac{p}{\Delta x_1} = \frac{y_1}{s_1} \quad (1)$$

$$s_1 = \frac{(\Delta x_1) y_1}{p} = \frac{a_1}{p} \quad (2)$$

The end-ordinate

$$s_e = \frac{\Sigma a}{p} = \frac{A}{p} = \frac{\text{Total Area ABCDEFA}'}{\text{polar distance}} \quad (3)$$

Thus, in order to obtain the desired sum or area, the ordinate (s) of the summation curve is multiplied by the polar distance (p); the length of the ordinate (s) is measured with the y -scale and expressed in y -units, while the length of the polar distance is measured with the x -scale and expressed in x -units.

If the polar distance is taken equal to X (the length of the base of the area $ABCDEFA'$), then the end-ordinate of the summation curve gives directly the mean height of the area $ABCDEFA'$, since

$$s_e = \frac{A}{X} = \text{Mean} \quad (4)$$

Thus far the summation curve considered has not been a true summation curve, for its ordinates are only the desired sum or area divided by an arbitrary constant; the ordinates of a true summation curve should represent the sum or area directly. The construction of a summation curve whose ordinates are the desired sum is easily carried out and also desirable because the multiplication with the polar distance is eliminated; furthermore, the ordinate scale of the summation curve can then be chosen to fit the needs of the problem. Let $ABCDE$ in Fig. 1 be a discharge curve so that its ordinates are Q in c. f. s. and its abscissas are time (t) in seconds. We now choose the desired moduli for Q , t and the sum (s) as follows:

$$\begin{aligned} 1 \text{ c. f. s.} &= m_Q \text{ inches} \\ 1 \text{ sec.} &= m_t \text{ inches} \\ 1 \text{ cu. ft.} &= m_s \text{ inches} \end{aligned}$$

and determine the polar distance accordingly. In the similar triangles P10 and A'B'G there is the following:

$$\frac{Q_1 \cdot m_Q}{s_1 \cdot m_s} = \frac{p}{\Delta t_1 \cdot m_t} \quad (5)$$

$$p = \frac{Q_1 \cdot m_Q \cdot \Delta t_1 \cdot m_t}{s_1 \cdot m_s} \quad (6)$$

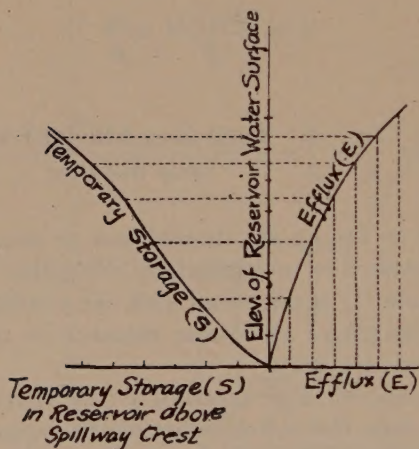


FIG. 2.— DETERMINATION OF CURVE OF VOLUME vs. EFFLUX

In the true summation, or mass, curve, the value of $s_1 = Q_1 \times \Delta t_1$ is desired and hence Equation (6) becomes —

$$p = \frac{m_Q \cdot m_t}{m_s} \quad (7)$$

or, more generally, —

$$p = \frac{m_y \cdot m_x}{m_s} \quad (7a)$$

where p is the length of the polar distance in inches, which must be used when the moduli of x , y and s are fixed in advance.

APPLICATIONS OF THE SUMMATION CURVE

The method of graphical integration by means of the summation curve will be applied to two hydraulic engineering problems: first, the determination of the equalizing effect (retention) of lakes or flood control reservoirs, and second, the evaluation of current meter measurements.

Equalizing Effect of Lakes and Reservoirs

When a river flows through a lake, its hydrograph is flattened and lengthened; the maximum efflux from the lake is less than the maximum influx to the lake and occurs later.

Assume the following as known:

(a) The hydrograph of influx to the lake during the passage of a flood wave.

(b) The area of water surface of the lake for different elevations of the water surface.

(c) The hydraulic characteristics of the water course into which the lake empties.

The problem is the determination of the hydrograph of efflux.

Let S_1 and S_2 = the temporary storage, *i.e.*, the volume stored in the lake or reservoir above the lowest point of the outlet cross section at times t_1 and t_2 , respectively

I = influx to the lake in c. f. s.

E = efflux from the lake in c. f. s.

ΣI and ΣE = respectively, the so-called mass influx and mass efflux, *i.e.*, the total volume of water which has flowed in and out, respectively, up to the time considered

$$t_2 - t_1 = \Delta t$$

We then have —

$$S_1 = \Sigma I - \Sigma E \quad (8)$$

$$S_2 = (\Sigma I + I \cdot \Delta t) - (\Sigma E + E \cdot \Delta t) \quad (9)$$

and —

$$S_2 - S_1 = I \cdot \Delta t - E \cdot \Delta t = \Delta \Sigma I - \Delta \Sigma E \quad (10)$$

The graphical solution begins at a time when the efflux through the outlet cross section is known: in lakes, at the instant when the efflux is still equal to the influx; and in reservoirs, the instant of first flow over the spillway. The latter case is treated here and in Fig. 4; it will be noticed that at the start I has a finite value and $E = 0$.

Plot the influx hydrograph (Fig. 4) to the right of the ordinate axis and then construct the influx mass curve by the method described above. To the left, the curve of temporary storage is plotted as a function of the efflux, so that its ordinates are E and its abscissa S ; this can be done, for the efflux is a function of the elevation of the reservoir water surface and therefore, also, of the volume of water temporarily stored in the reservoir. The method of determining this storage-efflux curve is indicated in Fig. 2.

In Fig. 3, say, E_1 is known or has just been determined. We assume E_2 and then determine graphically Δt , the interval of time at the end of which the efflux has increased to E_2 . When the efflux is E_2 the storage in the reservoir is S_2 ; the increment of or gain in storage ($S_2 - S_1$) is the horizontal distance between S_2 and S_1 , and is found graphically as shown at the left of Fig. 3. Take a pole at a polar distance (p) and draw the string P2 which gives the slope of the efflux mass curve for the desired interval Δt ; in doing so we knowingly commit the error of projecting E_2 on OY instead of the mean height of the trapezoid bounded by the efflux hydrograph, the time interval Δt , and the two ordinates E_1 and E_2 , but this error is insignificant if $E_2 - E_1$ is taken small enough.*

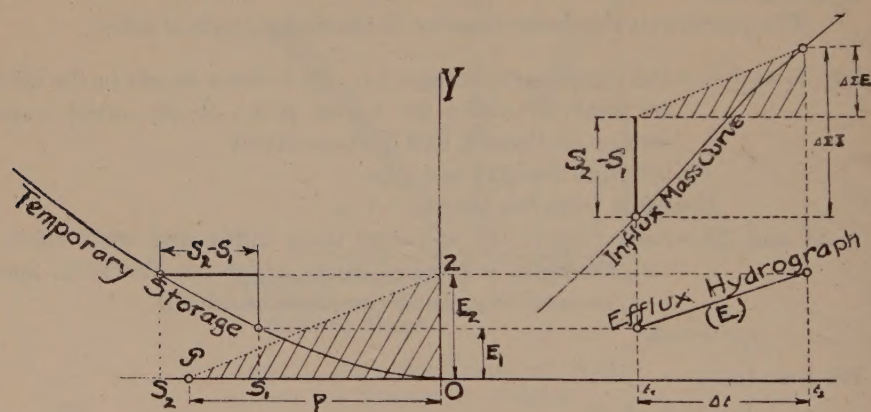


FIG. 3.—CONSTRUCTION OF ASCENDING PART OF EFFLUX HYDROGRAPH
(Enlargement of Construction in Fig. 4)

The storage-increment ($S_2 - S_1$) is now laid off vertically above the influx mass curve at t_1 , as shown at the right of Fig. 3; through the upper extremity of this transposed storage-increment draw a parallel to the string P2. The intersection of this parallel with the influx mass curve gives the time t_2 , and consequently, also, the desired interval Δt , for —

$$\Delta \Sigma I = (S_2 - S_1) + \Delta \Sigma E \quad (11)$$

By a progressive repetition of the process outlined, the hydrograph of efflux is constructed up to the point of maximum elevation of reservoir

* We could, indeed, use the mean height of the trapezoid. The method suggested is, however, clearer and facilitates checking, for each string terminates at the horizontal line joining E_2 of the efflux hydrograph with S_2 of the storage curve.

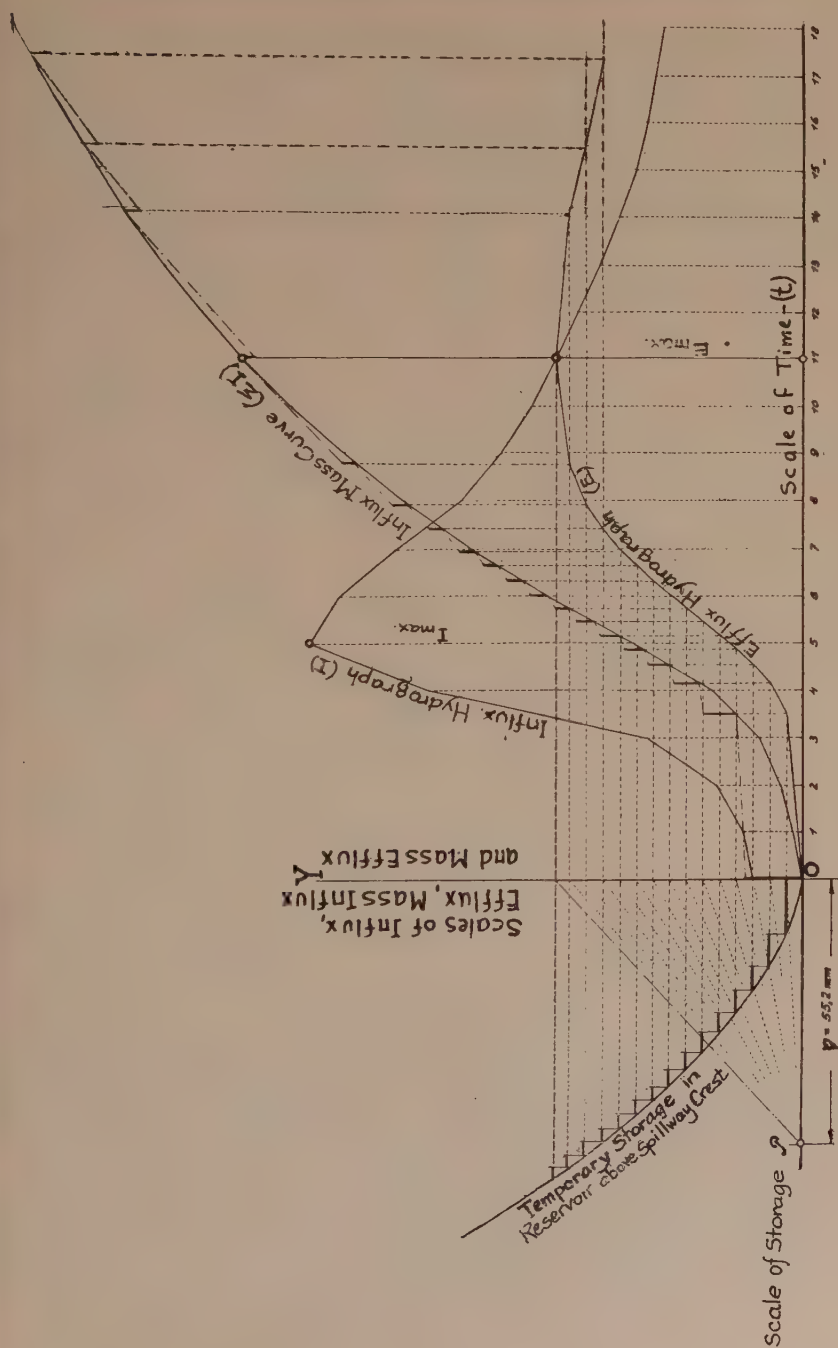


FIG. 4.— DETERMINATION OF EQUALIZING EFFECT OF RESERVOIR BY GRAPHICAL INTEGRATION

water surface, which occurs simultaneously with the maximum efflux from the reservoir. At this time influx and efflux are equal, and therefore the slopes of the mass curves of influx and efflux* are equal; furthermore, the tangent to the efflux hydrograph at this point is horizontal. With these facts in mind, we can determine the maximum efflux by trial.

The descending portion of the efflux hydrograph is constructed in a similar manner as the ascending part; however, during the recession of water level in the reservoir, the storage-increment is negative and is laid off vertically *below* the influx mass curve (Fig. 5). Note that we are con-

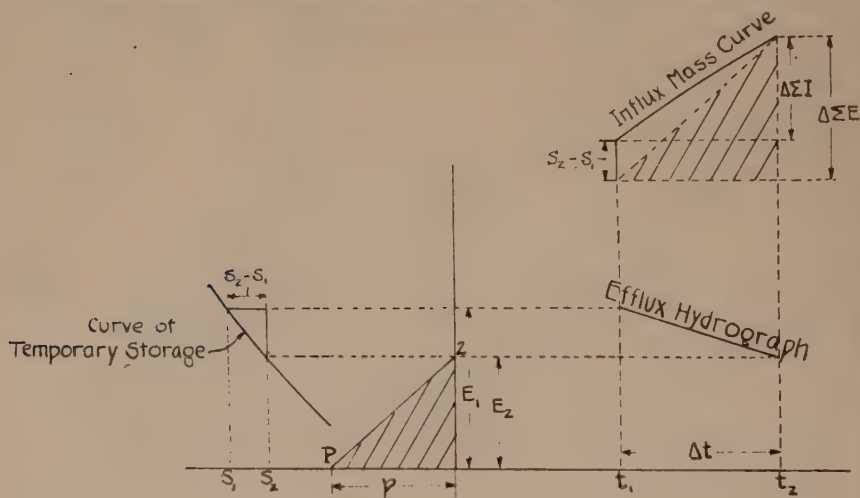


FIG. 5.— CONSTRUCTION OF DESCENDING PART OF EFFLUX HYDROGRAPH

sistently using the projection of E_2 (here the smaller leg of the trapezoid) in drawing the string P2.

After the point of maximum efflux, the influx and efflux hydrographs approach each other and eventually meet; the normal condition of lake efflux = lake influx is then restored. The mass curves of influx and efflux also come together at the same time. The difference in the ordinates of the two mass curves represents the volume of water temporarily stored in the lake.

A word about the scales of the graph. The scales of efflux and influx have the same modulus, m_0 ; the scales of temporary storage, mass influx and mass efflux all have the same modulus, m_s , while the modulus

* The mass curve of efflux is not drawn in Figs. 3, 4 and 5.

of time is m_t . These moduli are chosen to fit the needs of the problem, and the polar distance is computed by —

$$p = \frac{m_Q \cdot m_t}{m_s} \quad (7)$$

This is vital, for it renders possible the graphical constructions in Figs. 3, 4 and 5.

Evaluation of Current Meter Measurements

EXPLANATORY NOTES*

A few explanatory remarks on current meter measurements are necessary before consideration is given to the actual graphical solution.

If the distances between the verticals in which the velocity has been measured are bisected, then the area between two bisectors is considered to be the partial area belonging to the measuring vertical lying between the bisectors; the mean velocity in the measuring vertical is taken as the mean velocity in the partial area. The product of the mean velocity in the vertical and the partial area is the partial discharge.

The stage may vary during a current meter measurement. Accordingly, a different stage prevails during the measurement in each vertical; therefore it may be said that the stage at the first vertical is different from the stage at another vertical, although it is meant that a different river stage prevailed. A mean stage for the entire measurement is then determined in the following manner. The weight given to the depth of water or stage at each vertical is greater the larger the partial discharge is.

Let h = the elevation of the water surface at the different verticals referred to the elevation of the water surface at the first vertical; it may be plus or minus

a = the corresponding partial area

$\bar{v}$ = mean velocity in a

q = the corresponding partial discharge = $a \bar{v}$

Then the average stage H_M referred to the stage which prevailed at vertical I at the time of measurement is —

$$H_M = \frac{\Sigma h (a\bar{v})}{\Sigma a \bar{v}} = \frac{\Sigma h q}{\Sigma q} = \frac{\Sigma h q}{Q} \quad (12)$$

where Q is the total discharge through the entire cross section ($A = \Sigma a$).

The mean velocities in the verticals must now be adjusted to the depths of water in the partial area. If the mean velocity was $\bar{v}$ when the depth of water was d , and if the depth of water at the computed average stage is now d_a , then the following formula is accurate enough for the adjusted mean velocity $\bar{v}_a$ at the computed average stage:

$$\bar{v}_a = \bar{v} \left(\frac{d}{d_a} \right)^{0.7} \quad (13)$$

* From the Forchheimer Velocity Formula: $V = \frac{1}{n} S^{0.5} R^{0.7}$

THE GRAPHICAL PROCESS

The river cross section (F12345E) is plotted as shown in Fig. 6, where the measuring verticals are I-1, II-2, III-3, IV-4 and V-5. The partial areas are determined by drawing the bisectors of the distances between the different verticals. The stage prevailing at the time of measurement in the vertical is plotted as the stage of the corresponding partial area; the water surface is then temporarily a stepped line.

Each partial area may be looked upon as consisting of two sub-areas, one on each side of the vertical. The top of each sub-area is the water surface, its sides are a vertical and a bisector, and its bottom is a part of the river bed. We now displace each sub-area vertically upward or downward, so that its water surface is at the same elevation as that of the first vertical; this is done virtually by displacing vertically the center of the bottom of each sub-area by the amount h , as indicated by the heavy vertical lines on the river bed in Fig. 6. These shifted centers are projected on the straight line KL at the right of the cross section, and the Summation Curve I of cross-sectional area is constructed with a pole (P) located in the water surface of the first vertical at any desired polar distance (*e.g.*, $p = 50$ m.). The ordinates of this summation curve multiplied by the polar distance give the desired area. As will be seen from the following, no use intentionally is made of Equation (7), which would eliminate the necessity of this multiplication.

Now determine the mean velocity ($\bar{v}$) in each vertical by means of a summation curve as shown in the lower left corner of Fig. 6. The vertical velocity curve is replaced by a broken line fitting the curve as closely as possible. Place the pole at x , the foot of the measuring vertical, and take d , the depth of water in the vertical, as the polar distance. Then draw the summation curve which is merely the summation of the areas of the contiguous trapezoids whose bases are Δd and whose heights are v . The end-ordinate is then —

$$\frac{\text{Area under vertical velocity curve}}{\text{polar distance}} = \frac{\Sigma \Delta d \cdot v}{d} = \bar{V} \quad (14)$$

the mean velocity in the vertical.

We now proceed with the determination of the partial discharges and the mean velocity (V) in the entire cross section (A). The water surface at vertical I is produced to the right and through the point E, its intersection with the vertical line KL; on this extension (ET) the mean velocities ($\bar{v}$) in the verticals (computed beforehand) are plotted from E

as origin or zero. Note that the increments of the Summation Curve I from bisector to bisector are $\frac{a_I}{50}$, $\frac{a_{II}}{50}$, $\frac{a_{III}}{50}$, etc., since the polar distance is 50 m.; furthermore, these areas a_I , a_{II} , a_{III} , etc., are the partial areas in which the mean velocities $\bar{v}_I$, $\bar{v}_{II}$, $\bar{v}_{III}$ (just plotted) prevail. These increments $\frac{a_I}{50}$, $\frac{a_{II}}{50}$, etc., are now projected to the right on KL, as shown in Fig. 6. The partial discharges q_I , q_{II} , etc., to be determined can be visualized as fifty times the respective areas of contiguous rectangles whose bases are $\frac{a_I}{50}$, $\frac{a_{II}}{50}$, etc., and whose heights are $\bar{v}_I$, $\bar{v}_{II}$, etc.; these rectangles need not be drawn, for their bases $\frac{a}{50}$ are already projected on KL and their heights ($\bar{v}$) are already laid off on ET. Summation Curve II is, then, nothing more than the summation of the areas $\frac{a}{50} \cdot \bar{v}$ of the above-mentioned rectangles.

In choosing the pole and the polar distance for Summation Curve II, it must be noted that the mean velocity (V) in the cross section must also be determined. The pole is taken at L, the extremity of the end-ordinate of Summation Curve I, and the polar distance is EL, the end-ordinate of Summation Curve I. Note that the end-ordinate EL is $\frac{A}{50}$; furthermore, Summation Curve II is the summation of $\frac{a}{50} \cdot \bar{v}$. Then, according to Equation (4), end-ordinate of Summation Curve II is —

$$\frac{\sum \frac{a}{50} \cdot \bar{v}}{\frac{A}{50}} = \frac{\sum q}{A} = \frac{Q}{A} = V \quad (15)$$

which is the desired quantity. The increments of ordinate of Summation Curve II are —

$$\frac{\frac{a}{50} \cdot \bar{v}}{\frac{A}{50}} = \frac{a \bar{v}}{A} = \frac{q}{A} \quad (16)$$

as shown by $\frac{q_I}{A}$, $\frac{q_{II}}{A}$, etc., in the lower right part of Fig. 6.

The next step is the determination of the average stage during the current meter measurement. The differences in elevations h_{II} , h_{III} , etc., between the water surface at Verticals II, III, etc., and Vertical I, are plotted to an enlarged scale (5:1 or 10:1) on KL from E as origin

(+ above E, - below E). The problem is, then, the graphical solution of —

$$H_M = \frac{\sum h q}{Q} \quad (12)$$

Project the increments of ordinate, $\frac{q_I}{A}$, $\frac{q_{II}}{A}$, etc., on ET. Graphically sum up the areas (O , $\frac{q_{II}}{A} \cdot h_{II}$, $\frac{q_{III}}{A} \cdot h_{III}$, etc.) of contiguous rectangles whose bases are $\frac{q_I}{A}$, $\frac{q_{II}}{A}$, $\frac{q_{III}}{A}$, etc., and whose heights are O , h_{II} , h_{III} , etc. The ultimate purpose is, however, not the determination of $\sum \frac{q}{A} h$, but the determination of H_M ; accordingly, select EW (=V), the end-ordinate of Summation Curve II, as the polar distance and place the pole at W. The areas $\frac{q}{A} h$ are then summed up with Summation Curve III, which has for its end-ordinate —

$$\frac{\sum \frac{q}{A} h}{V} = \frac{\sum q h}{Q} = H_M \quad (17)$$

which is desired. H_M is then reduced to the original scale of stage in the cross section, and the average stage is plotted.

The mean velocities $\bar{v}$ in each of the verticals are now adjusted to this average stage by means of Equation (13).

The new uniform water level in the cross section changes the position of the center of the bottom of the triangular sub-area at each bank. The area of this adjusted cross section is now determined with Summation Curve IV; the true river bed drawn in Fig. 6 is used and not the displaced bed as for Summation Curve I. B_a , the width of the water surface at the average stage, is taken as polar distance, and the pole is taken at the intersection of the average water surface with the right bank. For the sake of clearness, all graphical constructions relating to the adjusted cross section are carried out on the left side of the cross section. The magnitude of the ordinate-increments of Summation Curve IV is $\frac{a_a}{B_a}$ and its end-ordinate (FG) is —

$$\frac{\sum a_a}{B_a} = \frac{A_a}{B_a} = D_a \quad (18)$$

the mean depth of the adjusted cross section.

The final step is the determination of the mean adjusted velocity (V_a) in the adjusted cross section (A_a) from the adjusted mean velocities ($\bar{v}_a$) in the verticals. Produce the average water surface to the left through F and plot on it the adjusted mean velocities ($\bar{v}_a$) from F as origin. Then project the ordinate-increments $\frac{a_a}{B_a}$ of Summation Curve IV on to MN. The plotted velocities $\bar{v}_{aI}$, $\bar{v}_{aII}$, and $\bar{v}_{aIII}$ can be looked upon as the projections of the heights of rectangles whose bases are $\frac{a_{aI}}{B_a}$, $\frac{a_{aII}}{B_a}$, $\frac{a_{aIII}}{B_a}$, etc. Now construct the Summation Curve V, using D_a (FG) as polar distance with the pole at G. The magnitude of the end-ordinate (FZ) of Summation Curve V is —

$$\frac{\sum \frac{a_a}{B_a} \bar{v}_a}{D_a} = \frac{\sum a_a \bar{v}_a}{B_a D_a} = \frac{Q_a}{A_a} = V_a \quad (19)$$

which is the desired adjusted mean velocity in the cross section. V_a multiplied by the adjusted area (A_a) of the cross section gives the discharge (Q_a) at the average stage of the measurement; and then the task is completed.

FINAL COMMENTS

The summation curve represents a simple and accurate method for the multiplication of two quantities, for the summation of quantities or the determination of the area under a curve, and for the determination of mean values. The reader will find that many other problems besides the given examples can be handled to advantage by this fascinating method.

The writer expresses here his sincere thanks to Dean Schoklitsch for valuable advice in the preparation of this article.

OF GENERAL INTEREST

B. S. C. E. HISTORY IN BRIEF

Howard A. Carson, who Died Recently, was Surviving Member of Group which Reorganized the Society on June 8, 1874, and Maintained Continuous Membership since that Time.

By Prof. John B. Babcock, Massachusetts Institute of Technology

The death of Howard A. Carson, Honorary Member and Past-President of the Society, on October 26, 1931, has removed the last name from the scroll of those engineers who on June 8, 1874, reorganized the Society after its lapse in activity following the Civil War period, and who had maintained a continuous membership in the Society since that memorable date. Mr. Carson occupied a high place in the engineering profession. A graduate of the Massachusetts Institute of Technology in 1869, he had served as a member of the Corporation of the Institute since 1878, and at the time of his death was its senior member. Included in Mr. Carson's notable engineering work was his service as Chief Engineer of the Metropolitan Sewerage Commission from 1887 to 1894, during the design and construction of that system, and later as Chief Engineer of the Boston Transit Commission from its inception in 1894 until 1909, during which period the Tremont Street Subway, the East Boston Tunnel and the Washington Street Tunnel were built. Mr. Carson served as consultant on subway and tunnel construction for many of the large cities in the United States. In

view of his connection with the Society from its reorganization in 1874 to the present date, it may be appropriate to review briefly the history of the Society from its organization in 1848.

On April 26, 1848, a group of five men, engaged principally in civil engineering, met informally at the United States Hotel in Boston to consider the expediency of forming a society for the promotion of their common interest in the profession of civil engineering. Those attending this meeting were John H. Blake, George M. Dexter, Ellis S. Chesbrough, Henry S. McKean and William S. Whitwell. At subsequent meetings attended by a dozen or so the organization of a civil engineering society was further discussed, and a draft of a Constitution and By-Laws presented. In these preliminary steps James Laurie, who later took such an active part in organizing the American Society of Civil Engineers, was a prominent figure. The first regular meeting of the Boston Society of Civil Engineers was held on July 3, 1848, at the rooms of the Boston Water Commissioners, and James F. Baldwin, who built the Boston & Lowell Railroad and took a prominent part in the introduction of a

public water supply into Boston, was elected president. Thus came into being the *Boston Society of Civil Engineers, the oldest engineering society in the United States!*

For the next few years the Society was very active, holding regular meetings at which its members presented papers on current engineering topics, building up a technical library, and taking part in various public affairs. The membership at that time was thirty-three, of whom a considerable number were located at some distance from Boston. Unfortunately for the Society the membership was becoming scattered, due to the increased opportunities for civil engineers in the development of railroads and water supply systems farther to the west, and gradually attendance at the meetings diminished, although those remaining near Boston continued their interest and activity in the Society. After much serious consideration it was decided to discontinue the meetings, and after 1862 the records indicate a lapse of twelve years. It is worthy of note that the same conditions affected the American Society of Civil Engineers, which was organized in 1852, and which ceased its activities during the period from 1855 to 1867, renewing its meetings in 1867 as a result of the unfailing interest and energy of its President, James Laurie.

On May 30, 1873, a group of twenty-six civil engineers met at the Massachusetts Institute of Technology to discuss the formation of an engineering society, and within a few months had adopted a Constitution and By-Laws and started regular meetings with Desmond FitzGerald as president. The first draft of the Constitution bore the name "Boston Society of Engineers," but on motion of Desmond FitzGerald the name was changed to the "Boston Society of Civil Engineers." This

change in name is most significant in the history of our Society, because it was soon discovered that this group had unwittingly taken the name of a Society still in corporate existence although at the time inactive. Immediate steps were taken for the consolidation of the two societies, and Ernest W. Bowditch, who had been active in the formation of the new society, took a prominent part in bringing these societies together. On June 8, 1874, an official meeting of the members of the "1848" Society was held, and on that date the individual members of the "junior" society were elected to membership in the original Boston Society of Civil Engineers, thus maintaining in continuous existence and renewing in activity the Boston Society of Civil Engineers, the oldest engineering society in the United States.

Of this group of about fifty members joining the Society on June 8, 1874, eleven were subsequently to serve as president, and many were to become civil engineers of the highest rank in their profession. Those who later became president of the Society in the order of their service were: Thomas Doane, Joseph P. Davis, L. Frederick Rice, Desmond FitzGerald, Clemens Herschel, Henry Manley, Dexter Brackett, Howard A. Carson, Alexis H. French, Frederick Brooks and Edward W. Howe.

Several years ago the Society voted that those who took part in the reorganization of the Society on June 8, 1874, should be listed as a group on the rolls of the Society in recognition of their services at that time and should be exempt from dues. In the 1926 Year Book of the Society the "1874" members, who had maintained a continuous membership in the Society for over fifty years, numbered six. These were Howard A. Carson, Desmond FitzGerald, Clemens Herschel, Edward W.

Howe, Wilbur F. Learned and Francis C. Tucker. At the time of his death, on October 26, 1931, Howard A. Carson was the sole surviving member of this notable group.

The senior member of the Society is now Prof. C. Frank Allen, a Past-Presi-

dent, who was elected to membership on March 24, 1875, one of the first to join the Society after its reorganization, and who has been one of our most active members for fifty-six years, — a record of which both the Society and Professor Allen may be justly proud.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS

Boston Society of Civil Engineers

SEPTEMBER 23, 1931. — A regular meeting of the Boston Society of Civil Engineers was held today. In the afternoon an inspection trip was made to the United States Arsenal at Watertown, under the leadership of Col. Tracy C. Dickson. About fifty members and guests attended, and, on being separated into groups with guides, they were conducted through various parts of the plant. One particularly interesting feature was the actual pouring of a casting for an anti-aircraft gun by the centrifugal method, the metal having been melted by an electric furnace.

Following this demonstration the groups visited the various laboratories for testing and control of processes of manufacture, including chemical analyses, X-ray examinations of castings and welding, the physical tests in tension, compression and impact, examination of texture by etching and photo-micrographic processes; also welding of flat steel of various shapes for gun mounts and the cutting of steel by torch, using ordinary illuminating gas under pressure.

The meeting in the evening in Chipman Hall, Tremont Temple, was called to order at 7.05 p.m. by the President, Harry E. Sawtell.

The President announced the death of Alger A. Conger, died May 26, 1931, member since April 20, 1921; Edward W. Howe, died June 27, 1931, member since

June 8, 1874; George F. Swain, died July 1, 1931, member since January 18, 1872, honorary member since September 19, 1917; Carl H. Nelson, died July 23, 1931, member since December 17, 1924; Frank P. Morrill, died July 26, 1931, member since January 27, 1909.

The Secretary announced that Max Paul Standke had been elected a member by the Board of Government.

The President, after expressing the appreciation of the members for the opportunity of seeing the work at the Watertown Arsenal this afternoon, introduced Colonel Dickson as the speaker of the evening.

In the talk, which was illustrated by lantern slides, Colonel Dickson described many of the activities at the arsenal, and the recent developments in the processes of manufacture of anti-aircraft guns by the centrifugal method which has been developed by him and which can well be expanded to meet all the requirements for this type of gun.

The utilization of the facilities of manufacturers of motor trucks for the development of a mobile unit of defence, adapting heavy six-wheel trucks for gun carriages, and the equally important fact of the great mileage of hard surface roads all over the country were emphasized. In presenting the matter of the manufacture of these guns mention was made of the various processes of examination and control by the various testing laboratories of the arsenal.

Adjourned at 9 p.m.

EVERETT N. HUTCHINS, *Secretary*.

Sanitary Section

OCTOBER 7, 1931. — At 6 P.M. 15 members and guests dined at Patten's Restaurant.

At 7.15 P.M. the meeting was called to order by the chairman, in the Library, with 25 members and guests present.

Before the presentation of the scheduled program, a brief description of the recent explosion at the Woonsocket sewage treatment works was given by Mr. Frank L. Flood, who had inspected the scene of the explosion. Photos of the wrecked plant were exhibited by Prof. Gordon M. Fair.

Reading of the minutes of the previous meeting was omitted, they having been published in the Journal.

The chairman then presented the speaker of the evening, Mr. Charles W. Sherman of Metcalf & Eddy, who spoke on the subject, "Financial Considerations of Municipal Sanitation."

He described the statutory limitations on municipal financing of sanitary projects, the customary methods employed for financing such projects, and more particularly the practice at Belmont, where he is a member of the Board of Water Commissioners.

Mr. Sherman then introduced Mr. Francis H. Kendall, Middlesex County Engineer and Belmont town official, and Prof. C. E. Fuller of M. I. T., Wellesley town official, who supplemented Mr. Sherman's talk with discussion of the subject in general and of their own experience.

Further discussion was made by the chairman and Messrs. Edward Wright, Frank L. Flood, John F. Pierce, and George G. Bogren.

Meeting adjourned at 9.15 P.M.

GEORGE G. BOGREN, *Clerk*.

Designers Section

OCTOBER 14, 1931. — A regular meeting of the Designers Section was called to order at 6.10 P.M. by the Chairman, Erwin Harsch, in the Affiliation Rooms.

The minutes of the May meeting were read and approved.

The Chairman reported the resignation of the clerk of the section, Raymond A. Freeman, who has accepted a position away from Boston, and announced that a new clerk will be elected at the November meeting.

The speaker of the evening was Prof. Kenneth C. Reynolds of Massachusetts Institute of Technology, John R. Freeman scholar of the Boston Society of Civil Engineers, 1927-29, who spoke on "The Correction Works for the Harbor of Wilhelmshaven, Germany, and the Protection Works on the Island of Wangeroog."

Professor Reynolds described the works built to prevent the German naval harbor being closed by shifting sands. He also described the laboratory where model tests were made to determine the best method of accomplishing this. The talk was illustrated by lantern slides showing the design of the correction works and photographs of construction.

At the conclusion of the talk there was a general discussion.

There were thirteen members and guests present.

The meeting was adjourned at 7.35 P.M.
LAWRENCE G. ROPES, *Clerk pro tem*.

APPLICATIONS FOR MEMBERSHIP

[October 20, 1931]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of fifteen (15) days from the date given.

For Admission

ALPERT, JOSEPH, Everett, Mass. (Age 21, b. Boston, Mass.) Graduate of Everett High School and now attending Northeastern University. During co-operative periods has been employed by the city of Waltham, A. C. Peters, and State of Massachusetts. Refers to *H. B. Alford, C. O. Baird, J. W. Copithorne, J. B. Komich*.

BENSON, GUNNAR S., Attleboro, Mass. (Age 22, b. Attleboro, Mass.) Student at Northeastern University and during co-operative periods has been employed by the New York, New Haven & Hartford Railroad for one and a half years; in the sanitary department, State of Massachusetts, and with the city of Attleboro. Refers to *H. B. Alford, C. O. Baird, C. S. Ell, J. B. Komich*.

BRADFORD, GEORGE HENRY, JR., North Raynham, Mass. (Age 22, b. Boston, Mass.) Student at Northeastern University and during co-operative periods has been employed by the city of Newton, and for a short time previously by Cobb, Beesley & Miles. Refers to *H. B. Alford, C. O. Baird, J. B. Komich, W. E. Nightingale*.

CAPONIGRO, JOSEPH GELSOMINO, East Boston, Mass. (Age 26, b. Campagna, Province of Salerno, Italy.) Senior at Northeastern University. Refers to *H. B. Alford, C. O. Baird, A. A. Minichiello, W. E. Nightingale*.

HOWARD, PAUL F., Winthrop, Mass. (Age 31, b. Winthrop, Mass.) Graduate of Tufts College with degree B.S. in civil engineering. Inspector for Massachusetts Department of Public Works summers of 1921 and 1922; taught mathematics at New Hampshire University, 1922-23; in the employ of Whitman & Howard, 1923-29. Received degree of Master of Science from Harvard University in 1930. Member of firm of Whitman

& Howard since 1924. Refers to *H. P. Burden, G. M. Fair, Channing Howard, H. E. Sawtell*.

MARTIN, H. GORDON, Needham, Mass. (Age 23, b. Needham, Mass.) Student at Northeastern University. During co-operative periods worked for Brook's Engineering Company, and Harold Martin Construction Company. Refers to *H. B. Alford, C. O. Baird, J. W. Copithorne, J. B. Komich*.

MCGRATH, JOHN FRANCIS, Milton, Mass. (Age 24, b. Milton, Mass.) Attended night school at Northeastern University for three years and continuing this study. From December, 1926, to June, 1929, employed as rodman by the town of Milton; from June, 1929, to June, 1931, transitman; and from June, 1931, to date as chief of party for the town of Braintree. Refers to *J. H. Bowie, C. F. Joy, F. J. Maynard, G. N. Watson*.

PEARSON, C. ROGER, Norwood, Mass. (Age 29, b. Norwood, Mass.) Graduate of Northeastern University with degree of Bachelor of Civil Engineering. Inspector on State highway to January, 1923; with Whitman & Howard from 1923 to date, and member of firm since 1924. Refers to *H. B. Alford, Channing Howard, W. E. Nightingale, H. E. Sawtell*.

RACICOT, HENRY ALEXANDER, Webster, Mass. (Age 22, b. Webster, Mass.) Student at Northeastern University and during co-operative periods employed by the city of Waltham in the engineering department; also for the State. Refers to *H. B. Alford, C. O. Baird, J. W. Copithorne, J. B. Komich*.

ROCHE, RAY J., East Braintree, Mass. (Age 26, b. Tombstone, Ariz.) Graduate of La Salle Academy, Providence, R. I., 1922. 1918-20, rodman with Unit Construction Company, on New England Oil Company plant at Fall River; 1921, transitman with New York, New Haven & Hartford Railroad; June, 1922, to August, 1923, with E. M. Corbett, Engineer, Fall River; graduate of Yale, June, 1927; July, 1927, to May, 1928, division engineer, Sonora; June, 1928, to August, 1928, Union Pacific Railroad, Cheyenne, Wyo.; August, 1928, to October, 1929, with Union Pacific Railroad as assistant division engineer; November,

1929, to June, 1930, engineer-surveyor; June, 1930, to date, senior engineering aide in the Massachusetts Department of Public Works. Refers to *A. B. Appleton, H. B. Frye, A. J. Giuranovich, A. E. Kleinert, F. H. Morris.*

THACHER, H. FISK, Natick, Mass. (Age 21, b. Franklin, Mass.) Entered Northeastern University in the fall of 1928. During his co-operative periods has been employed by the city of Newton for the last three years, and previous to that was with Lloyd-Thomas Company of Chicago. Refers to *H. B. Alword, C. O. Baird, J. W. Copithorne, J. B. Komich.*

For Transfer from Grade of Junior

COBB, EDWIN BLAINE, Norwood, Mass. (Age 24, b. Norwood, Mass.) Graduate of Northeastern University, 1929. With J. J. Van Valkenburgh, June, 1929, to May, 1930, as resident engineer sewer and waterworks, Framingham; May, 1930, to August, with city of Springfield as concrete inspector on the Cobble Mountain Outlet Tunnel; August, 1930, to January, 1931, with Metcalf & Eddy as inspector on waterworks construction; April, 1931, to date, with Weston & Sampson as resident engineer on water supply at Wilton, N. H. Refers to *H. B. Alword, G. G. Bogren, F. A. Marston, G. A. Sampson, J. J. Van Valkenburgh.*

LAVERS, WILLARD DOUGLAS, Salem, Mass. (Age 26, b. Nova Scotia.) Graduate of Northeastern University in 1926. While in school was employed during co-operative periods by the town of Belmont, town of Dartmouth, and by P. J. Leary of Lynn, as instrumentman; since graduation has been with Stone & Webster Engineering Corporation, on the construction of Conowingo Dam, American Sugar Refinery in Brooklyn, and Hartford National Bank & Trust Company, as instrumentman and inspector; January to August, 1929, with Alonzo B. Reed as resident engineer; September, 1929, to May, 1931, with Stone & Webster Engineering Corporation as field engineer on construction of Western Plant of Lever Brothers Company, Hammond, Ind., and the Rock Island Hydro-Electric Development near Wenatchee, Wash.;

August and September, 1931, with P. J. Leary Company, Lynn, on land surveying. Refers to *H. B. Alword, G. D. Brown, D. S. Neil, W. N. Patten, A. B. Reed.*

MAYALL, R. NEWTON, Cambridge, Mass. (Age 27, b. Waltham, Mass.) From 1922 to 1926 worked for Barnes & Beal, civil engineers of Waltham; 1926 to date, for A. A. Shurcliff, Landscape Architect. Studied at Architectural Club for two years and extension courses at Harvard, and now studying at Harvard for degree of A.A. Refers to *W. E. Nightingale, W. F. Pike, C. H. Stimpson, J. W. Urquhart.*

RAE, ARTHUR N., Jamaica Plain, Mass. (Age 24, b. Boston, Mass.) Graduate of Northeastern University in 1927. During co-operative periods was transitman with Schein & Levine, Engineers; June to September, 1927, structural draftsman with Burtis S. Brown, Engineer; October, 1927, to date, estimator and construction engineer with Vincent E. Squiers, General Contractor, Newton Highlands, and at present studying law in Northeastern evening school. Refers to *H. B. Alword, C. O. Baird, C. S. Ell, W. E. Nightingale.*

SMITH, LOUIS HART, Somerville, Mass. (Age 26, b. New Orleans, La.) Graduate of Northeastern University, 1927, with degree of Bachelor of Civil Engineering. During co-operative periods worked with Whitman & Howard as transitman and chief of party from April, 1924, to December, 1926; from December, 1926, to June, 1927, with New York, New Haven & Hartford Railroad as chainman; from August, 1927, to date, with Metropolitan Planning Board as junior civil engineer. Refers to *H. B. Alword, A. B. Edwards, W. E. Nightingale, E. H. Rogers.*

WOLFRUM, CARL ADAM, Jamaica Plain, Mass. (Age 26, b. Boston, Mass.) Graduate of Mechanic Arts High School and of Northeastern University in 1926. During co-operative periods employed by Aspinwall & Lincoln from June, 1926, to March, 1931, as assistant engineer; from April, 1931, to July, with Fred A. Joyce, Belmont, as assistant engineer; July, 1931, to date, with Aspinwall & Lincoln as assistant engineer. Refers to *H. B. Alword, L. A. Chase, H. G. Gray, F. F. Hampe, K. D. Sylvester.*

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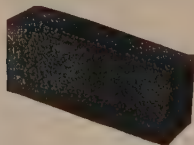
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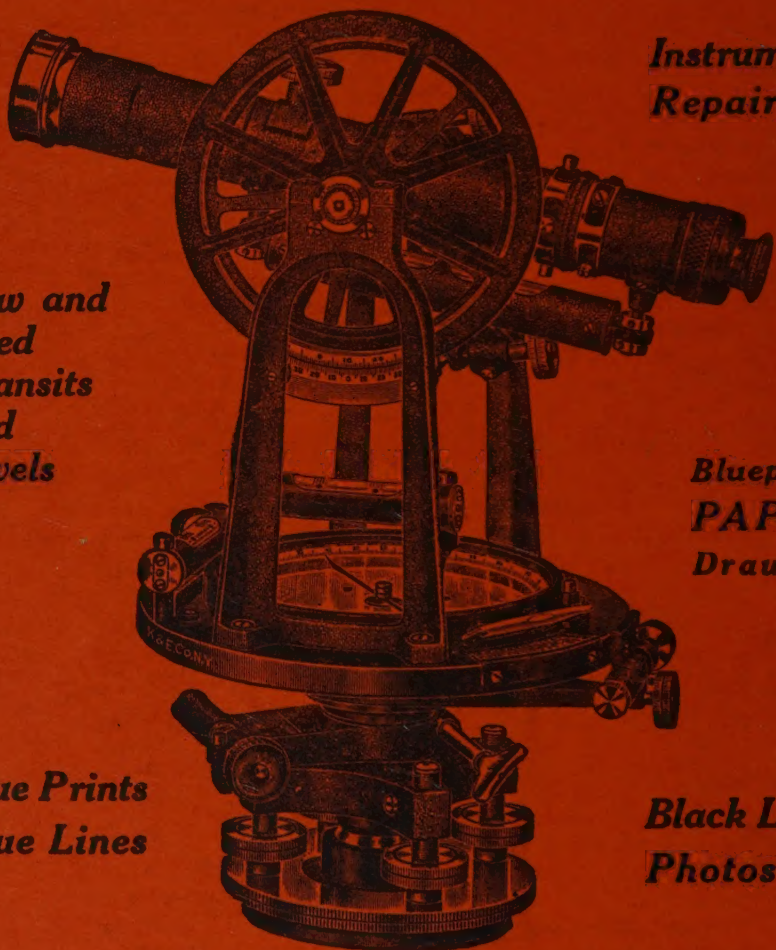
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